EJSM

Risk Mitigation Plan:
Radiation and Planetary Protection
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Dedicated

in

Memory

of

A friend, classmate, and colleague

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Who prepared the first Draft

Of

This document

Executive Summary

Planetary scientists have long been interested in a mission to Europa with the goal of investigating its icy shell, studying the extent of its subsurface ocean and understanding its place in context with the Jupiter system. The Jovian harsh radiation environment presents significant technical challenges for designing a long duration mission to Europa. Data collected from Pioneers 10 and 11, Voyagers 1 and 2, and Galileo indicates that the radiation exposure of electronic parts may be as high as 3 Mrad (±0.5 Mrad) Si dose behind 100 mils of aluminum during the entire mission lifetime.

The objective of this plan is to mitigate the development and operational risk posed to the spacecraft and instruments of the proposed Jupiter Europa Orbiter (JEO) (the US portion of the EJSM). In addition, the plan would facilitate trades among mission lifetime, mass and power requirements, while meeting science objectives and reducing lifecycle cost. This four-year plan is based on the approach and strategy outlined in the 2007 Europa Explorer (EE) Mission Study Report. It also factors in the recommendations of the 2007 NASA Science, Technical, Management and Cost (TMC) Review team. Successful execution of this plan would retire a majority of the radiation risks approximately at the beginning of Phase A, assuming a launch year of 2020. If a 2018 launch year (about 17 months earlier than the 2020 opportunity) is ultimately selected, this plan would complete closer to the end of Phase A, which would match a mission development schedule.

The effort in this work plan includes compliance with the NASA planetary protection (PP) requirements that were established based on recommendations set by the Committee on Space Research (COSPAR), a part of the International Council for Science. Although the PP activities are not included as part of this work plan, the PP compliance would be achieved through coordinating and planning of parts and materials selection with understanding of the radiation environment.

Currently, JPL exercises extreme conservatism in designing and verifying spacecraft electronics subsystems, which often leads to excessive design margins and severely underestimates the mission lifetime. This commonly results from a compounding effect of applying worst-case assumptions at every level: from parts selection to system design and engineering. This work plan addresses this deficiency by developing a system-level approach of quantifying the uncertainties through rigorous analysis and validation through laboratory testing. The resulting system lifetime model; Jovian radiation model; radiation design methodology and guideline; parts selection and testing strategy for various dose rate conditions and annealing effect; and assessment of radiation effects on sensors and detectors of science instruments would establish a defined pathway to quantitatively perform trades in the mission and science value space. Application of this system approach for radiation mitigation offers a new paradigm in the underlying process for long duration mission designs. In this work plan realistic mission conditions and design guidelines will be developed to improve the traditional process and simultaneously provide an accurate picture of estimating mission lifetime.

The selection of electronic parts for radiation susceptibility and reliability presents the first hurdle to be overcome for the proposed JEO mission. Commercially available parts advertized to be compatible with environments of 100 krad up to over 1 Mrad are generally not heavily used nor tested for long duration missions. Parameter degradations due to high radiation exposure levels have not been fully characterized and documented. This work plan includes the development of an Approved Parts and Materials List (APML), which is a list of pre-screened acceptable parts and their design parameters. Significant risks would be mitigated by focusing on the evaluation, testing and characterization of critical devices, such as Field Programmable Gate Array (FPGA), memory, power converters and linear devices, early in the planning and development cycle. Timely dissemination of this information to spacecraft and instrument providers is critical in order to enable them to adequately design for the aggressive radiation environment and assess the impact of PP requirements on payload science and engineering sensors and detectors.

This plan was prepared in support of the proposed Europa mission though substantial aspects could be utilized by other missions in general, and specifically for a possible future Titan mission. The plan spans four years, but focuses primarily on FY'08 and FY'09 budgets and activities. The phasing of tasks and the performance metrics are driven by the tentative milestones that are based on a September 2018 launch opportunity.

1. Table of Contents

1. Introduction

Early risk assessment and mitigation activities could severely impact the development and operational costs associated with challenging missions. It is paramount to assimilate design methodologies and considerations for long duration missions early in the planning and conceptual phase. This is eminently crucial for missions encountering aggressive radiation environments and stringent planetary protection requirements. This document describes a systematic implementation approach to assuage mission development and operational risks specifically for the proposed Jupiter Europa Orbiter (JEO), though substantial aspects of it are applicable to other long duration missions. The underlying work plan will facilitate effective trades among mission lifetime, mass and power requirements while meeting science objectives and reducing lifecycle cost.

A detailed three-year radiation risk mitigation plan was developed in early FY'08 based on the approach and strategy outlined in the 2007 Europa Explorer (EE) Mission Study Report. The plan also factors in the recommendations of the 2007 NASA Science, Technical, Management and Cost Review team, which would support a FY'08 Phase A start with a 2015 or 2017 launch opportunity. Midway through the FY'08 study, the nominal launch year was moved to 2020. However, the proposed JEO mission could be launched as early as 2018. As such, the three-year plan was re-evaluated to a four-year plan to be compatible with a launch in 2018. Some elements of the plan are more time critical than others. This four-year plan will retire a majority of the radiation risks approximately at the beginning of Phase A, assuming a launch year of 2020. If a 2018 launch year (about 17 months earlier than the 2020 opportunity) is ultimately selected, this plan would complete closer to the end of Phase A.

1.1 General Description

The plan includes the development of design tutorials, an Approved Parts and Materials List (APML), and radiation design guidelines for potential instrument providers; assessment of radiation effects on sensors and detectors of science instruments; evaluation of the availability of radiation-hardened parts such as Field Programmable Gate Array (FPGA), memory, power converters; identification and testing of electronic parts; measurements of these parts under various dose rate effects; and establishment of a mission lifetime estimation methodology when subjected to different radiation effects based on the electronic parts database.

This plan was prepared in support of the proposed Europa mission though substantial aspects could be utilized by a possible future Titan mission. For example, the APML contains information suitable for long life missions and parts information at 50 Krad, 100 Krad, 300 Krad, and 1 Mrad. This range covers the Titan and the Europa radiation environments. Also, the Long Life Design Guidelines are applicable to missions in general, and specifically for possible future Titan and Europa missions.

The plan spans four years, but focuses primarily on FY'08 and FY'09 budgets and activities. This plan will be assessed and updated when early device evaluations are completed; the preliminary design guidelines are developed and reviewed; and at least annually to account for changes in the environment. This plan contains relevant activities from investments including those from the NASA Europa Jupiter System Mission (EJSM) study, NASA Electronics Parts Program (NEPP), JPL Research & Technology Development (R&TD) and JPL outer planets radiation investments. There are six major elements in the Work Breakdown Structure (WBS) of this work plan:

1. System Reliability Model;
2. Environment and Shielding Models;
3. Radiation Design Methods;
4. Sensors and Detectors;
5. Parts Evaluation & Testing; and
6. Approved Parts and Materials List.

The effort in this work plan includes compliance with the NASA planetary protection (PP) requirements that were established based on recommendations set by the Committee on Space Research (COSPAR), a part of the International Council for Science. The final impact of the proposed Jupiter Europa Orbiter (JEO) on the Europan surface means that the mission would most likely be classified as a category III under the current COSPAR and NASA policies.

The original version of this plan was presented at an all-day workshop with JPL and Applied Physics Laboratory (APL) participation on February 11, 2008. It was further developed, refined and reviewed by the top engineers representing the JPL Office of Mission Success on March 7, 2008.

1.2 Objective and Approach

The objective of this plan is to mitigate the development and operational risk of spacecraft and instruments for the proposed Jupiter Europa Orbiter (JEO) (the US portion of the EJSM) and facilitate trades between mission resources and science value. The benefits of the plan include lowering development and operational risk, while enabling more effective trades among mission lifetime, mass, science, cost, and other factors. These factors can be quantified through rigorous analysis and validated through laboratory testing when exposed to the aggressive radiation environment.

The implementation approach is to extend work started under Europa Explorer in 2006 and 2007 by developing a system-level reliability model for radiation risk reduction. This effort, corresponding to each WBS element, includes:

- Developing a new integrating tool set to allow system engineering to effectively manage risk, resources and science value
- Developing higher fidelity environment and shielding models
- Developing and documenting design and analysis guidelines for parts de-rating, worse case analysis, and circuit performance
- Developing and documenting parts testing requirements for parts degradation and actual failure characteristics
- Testing and characterizing electronic parts, materials, sensors and detectors to support design trades and solutions
- Developing a list of approved parts and materials to enforce design discipline and reduce risk.

This plan supports the following milestones based on a September 2018 launch opportunity:

- FY'08: Identify and obtain highest impact design information for dissemination to the Instrument community for the instrument workshop in June 2008 and November 2009.
- FY'09/10: Complete design data gathering and dissemination to the design community, evaluate and structure proof-of-concept system model including identifying required input information to support the release of instrument Announcement of Opportunity (AO) and preparation of System Safety Review (SSR) / Mission Definition Review (MDR).
- FY'11: Complete system model and input parameter definitions to support subsystem and instrument Preliminary Design Reviews (PDR) in FY'12.

1.3 4-Year Roadmap and schedule

A roadmap has been developed for the four years, FY'08 – FY'11. The phasing of tasks within each WBS element and the performance metrics are driven by the following tentative milestones that are based on a September 2018 launch opportunity:

- Instrument workshop – June 2008, November 2009
- Mission Concept Review – March 2010
- Instrument AO – September 2010
- SRR/MDR – March 2011
- Subsystems PDR – July 2012

Tasks within each WBS element are prioritized to meet the instrument workshops and the Instrument AO schedule. The system engineering design, system reliability model, and design guidelines are needed for the SRR/MDR and the preliminary engineering design needed for the PDR.

The Roadmap is shown in Figure 1.1. The 1st column contains the work breakdown and the major subtasks for each work element. The 2nd column contains information on the current state of the capability of JPL from a mission capability standpoint. The 3rd column contains information on the capability at the end the 2007 Europa Concept study. The remaining columns show the plan for the next four years. Quantitative performance metrics are used wherever possible. For example, in WBS 1.0, the mission lifetime reliability model used expert opinions to capture the statistical electronic parts failure statistics in FY'07, and in FY'10, 7 of the 11 part families would have actual data to replace expert opinions. This roadmap is used to define radiation risk mitigation progress needed to support the major mission milestones and it would be used to develop the detailed schedule.

RADIATION RISK MITIGATION ROADMAP	JPL SOA	FY07	FY08	FY09	FY10	FY11
PROJECT MILESTONES					MCR ∇ IAO ∇	∇PMSR
1.0 System Reliability Model	Parts focus	Systems engineering focus using PRA				
Systems Level Understanding of Risk	Limited	Conceptual	Basic	Improved	Enhanced	Detail
Component Life Model (Number of part families incorporated)	None	Expert Opinion	2/11	3/11	11/11	11/11
Circuit Life Model (Number of circuit type incorporated)	None	None	None	2/6	4/6	6/6
System Elements	None	H-Level Abstraction	Characterize	Preliminary	Interim	Interim
Validation	None				Plan	Preliminary
2.0 Environment & Shielding Model	Limited/ Qualitative	Quantitative				
External Environment Model Uncertainty: Temporal	Limited/Qualitative	Limited/Qualitative		High	Low	
Environment Model (Proton, Heavy Ion, Directionality, Temporal behavior)	*None*	None		Plan	Preliminary	Final
Shielding Model (Interaction Cross Section, Mass)	*None*	None		Preliminary	Final	
3.0 Radiation Design Methods	None					
Environment & Shielding Tutorial & Guidelines		Draft	Draft	Preliminary	Final	Final (Shielding)
Electronic Parts and Circuits Tutorial & Guidelines		Draft	Draft	Preliminary	Revision	Final
Materials Tutorial & Guidelines		Draft	Draft	Final		
Subsystem & System Design Guidelines		None	Initial Design	Fab HW & Rad Test	Revision	Final
Radiation Engineering Plan		None	Draft	Preliminary	Revision	Final
Bus Core FPGA ASIC Architecture (MSAP)				Preliminary	Revision	
4.0 Detectors & Sensors	N/A					
System-level understanding of detector radiation risk			Low	Medium	Medium	High
Determine Rad Env at Detector/component w/ shielding			Preliminary	Final		
Science Sensors Assessment & Testing (Visible, Infrared, Ultraviolet, etc)			DDD Testing Notional Det	TID/DDD Testing in Flt-Like Env	Inst Providers Char Flt-Like Det	Inst Providers Char Flt-Like Det
Engineering Sensors Assessment & Testing (Star Tracker)			Preliminary	Final		
5.0 Parts Evaluation & Testing	N/A					
Annealing Effects Evaluation & Guidelines			Preliminary	Final		
Testing Strategy & Guidelines (ELDRS, Displacement, Combined TID/Displacement)			Evaluation & Recommendation	Preliminary Req Doc	Final Req Doc	
Juno Extended Testing			6	18	22	24
Device Evaluation & Testing (Non-Volatile Memories, FPGA, Power Converters, Micro-processors/Controllers, Data Bus Devices, Linear)		Limited	Preliminary	Final	Final (Linear)	Final (Linear)
6.0 Approved Parts & Material List	None					
Project Parts Requirements Document			Final			
Preferred Parts & Material List (PPML) and Worst Case Data sheet (WCD)			150 parts & material list and 20 WCD	300+ parts & material list, 100+ WCD	Quarterly Updates	Quarterly Updates
Parts Parametric Design Approach			5/11 part families	8/11 part families	11/11 part families	

Figure 1.1 Radiation Risk Mitigation Plan Roadmap

1.4 Planetary Protection

Planetary protection (PP) requirements aim to prevent terrestrial microbial contamination on extraterrestrial Solar System bodies, and to protect the Earth and Moon from potential extraterrestrial Solar System material contamination returned by such missions. The NASA HQ PP Officer establishes PP requirements based on recommendations set by COSPAR, a part of the International Council for Science. The NASA PP Officer imposes the PP requirements on U.S. planetary missions where compliance is mandatory. PP requirements for Europa are a significant challenge. The final fate of the proposed JEO impacting the Europan surface means that the mission would most likely be classified as a category III under the current COSPAR and NASA policies. Therefore, our PP compliance approach is a combination of controlled bioburden (by sterilization processing before launch) and exposure to radiation from the Jovian environment prior to Europa orbit insertion. Prior to launch, the preferred method of microbial reduction is dry heat microbial reduction (DHMR). In order to achieve compatibility for the mission hardware, it is necessary to consider DHMR (elevated temperature) compatibility in the trade studies alongside the radiation resistance.

In this plan, PP compliance is achieved through close coordination and planning between the PP requirements and two WBS elements: WBS 4.0 – Sensors & Detectors and WBS 6.0 – APML. In the APML, a column designates the PP compliance. This list would be provided to instrument and spacecraft providers to understand the impact of PP requirements on payload science and engineering sensors. Even though, for EJSM, the PP activities are not included as part of this work plan, significant interaction with the PP activities are anticipated to achieve the compliance for parts and materials selection and understanding of the radiation environment for the sensors and detectors.

2. Work Breakdown by Elements

2.1 System Reliability Model

2.1.1 Introduction

Currently, JPL incorporates excessive conservatism in designing and verifying spacecraft electronics subsystems, which often leads to distributed hidden design margins and severely underestimates the mission lifetime. Parts radiation testing is generally stopped when the specification is met; which provides no information about when actual part failure occurs. Analyses compound extremely conservative de-rating factors and parameter values to show margin against sometimes unrealistic conditions. Therefore, predicted mission lifetimes are lower than actual values due to the large amount of design margins. Two recent examples are:

- Galileo, which has designed for a 3 year mission at Jupiter but was still functioning after 8 years when the mission was terminated; and
- The Mars Exploration Rovers (MER), which were launched in the summer of 2003 (June 10 and July 7), each with an intended 90 day mission on the surface but remain operational today (> 4 years).

2.1.2 Objective and Approach

The objective of this WBS element is to improve the JPL approach to long life mission design by developing the capability to predict lifetime, based on first principles, design practices and parts statistics, in order to judiciously use prudent margins for refined trades among mission lifetime, mass, science, cost, and other factors.

The implementation approach is to extend work previously started under Europa Explorer in 2007 by developing a system reliability model with lifetime estimation. The key steps are to utilize:

- new parts degradation and failure characteristics from extended Juno parts testing, EJSM part list and part vendors for parts model,
- representative spacecraft and instrument critical circuits for circuit models;

and to extend:

- current modeling capability to include 1) realistic parts statistics, 2) circuit degradation statistics, and 3) system element functions;
- current model to include fault protection functions, e.g. redundancy and cross-strapping and finally validate the model by tests.

Specific deliverables for each year are:

- FY'08: Statistical model using the Master Equipment List (MEL)
- FY'09: Statistical model for 3/11 part families and 2/6 circuits
- FY'10: Statistical model for 7/11 part families and 4/6 circuits
- FY'11: System model for all critical system elements, fault protection and validation

2.1.3 Roadmap and Schedule

The key attributes of the system reliability model are:

1) to improve the understanding of the system reliability from conceptual to detailed design and operations;
2) to reduce reliability uncertainty from high to low as design matures; and
3) to migrate from high and qualitative component margin to prudent and quantitative component margin.

The roadmap lays out an approach to enable these attributes in 4 years.

There are 6 activities within this WBS element. The 1st activity is to update the radiation environment model by adding shielding uncertainties and to include the temporal variation of the radiation model at Europa.

The 2nd activity is to replace the parts reliability statistics from expert opinion used in the 2007 model by the relevant JUNO extended parts testing at the EJSM level, beginning with the weakest interface parts then building up the information using remaining parts. This approach would allow working the highest priority problems before the system model is too complex to gain good insights. As part of this activity credible de-rating criteria using new parts degradation and failure statistics would be developed. Furthermore, 6 representative circuits would be selected, which have the major features for long life and radiation issues. The tentative circuits identified currently are:

- DC/DC power converter
- FPGA design with transformer coupler isolation

- Data bus interface circuit
- Camera front end analog signal circuit
- Communications front end signal conversion circuit
- Laser altimeter main electronics circuit

Circuits developed would be tested to validate analytical prediction of circuit degradation. These test results are valuable sources to validate the system reliability model. Outputs of this work would support the development of detailed design and analysis guidelines for circuits.

The 3rd activity is to extend circuit level reliability information to system elements including spacecraft and instruments. The modeling process would begin by incorporating the weakest element, and then extend to handle interface elements and all other elements contributing to lifetime estimation. The most sensitive elements would be identified and the risk information of these elements would be quantified using the system reliability model. A detailed understanding of the end-to-end data flow would be performed to understand and characterize the system elements relationship to critical mission data.

The 4th activity is to establish a system engineering approach for modeling radiation and related effects that would recognize and properly apply probabilistic radiation lifetime statistics in the mission and system trade space. For example, operating parts at high temperatures is generally detrimental to reliability. However, annealing away radiation damage offers a net benefit in some instances. The trade study would consider both effects and determine how best to exploit annealing and other life-extending approaches.

The 5th activity is to relate system lifetime modeling to the end to end science value and establish a methodology to quantitatively perform trades in the mission and science value space.

The last activity is the integration of the radiation related lifetime model and the traditional methods of system lifetime prediction.

The metric of performance for the activities is identified in the system reliability model roadmap and they are documented in Figure 2.1.

LIFE TIME MODEL FEATURES AND CAPABILITIES SYSTEM RELIABILITY		Capabilities implemented by Version				
		Version 0	Version 1	Version 2	Version 3	Version 4
	JPL SOA	FY07	FY08	FY09	FY10	FY11
PROJECT MILESTONES					MCR▽ IAO▽	▽PMSR
MISSION RELIABILITY OVERVIEW						
JPL approach to assuring reliability	Parts focus	Systems engineering focus using PRA				
Key Features						
Systems level understanding of risk	Limited	Conceptual	Basic	Improved	Enhanced	Detail
Reliability uncertainty	High	High	High to Medium	Medium	Medium to Low	Low
Component margins	High/Qualitative	High/Quantitative			Prudent/ Quantitative	Prudent/ Quantitative
ENVIRONMENT MODEL						
Statistical Model						
*Incorporate shielding model**					Final	
*Remove time dependent uncertainty in radiation model at Europa**						Final
COMPONENT LIFE TIME MODELS						
Statistical Model	*None*					
Incorporate real parts data						
Expert opinion		High	High to Medium	Medium	Medium to Low	Low
*Relevant Juno parts at EJSM levels**			Preliminary	Final		
*EJSM parts at EJSM levels - weakest & interface**			Identification	Evaluation	Preliminary	Final
*EJSM parts at EJSM levels - remaining**				Evaluation	Evaluation	Preliminary
Number of part families incorporated			2/11	3/11	7/11	11/11
*Develop Derating Criteria**			Preliminary	Interim	Interim	Final
Input to Instrument AO			Preliminary	Complete		
CIRCUIT LIFE TIME MODEL						
Statistical Model	*None*					
Number of circuit type incorporated		None	None	2/6	4/6	6/6
Circuit level validation				Plan	Preliminary	Final
*Analysis & Design Guidelines**				Prelim	Interim	Final
SYSTEM LIFE TIME MODEL						
Statistical Model	*None*					
Model for weakest system elements			Identify	Characterize	Preliminary	Final
Extend model to interface system elements			Identify	Characterize	Preliminary	Final
Extend model to other system elements				Characterize	Improve	Preliminary
Refine system elements with highest sensitivity					Preliminary	Interim
System level validation					Plan	Preliminary
** Performed in other WBS but part of an integrated effort*						

Figure 2.1 WBS 1.0 Roadmap – System Reliability Model

2.1.4 Applicability to Other Missions

This WBS element is applicable to other missions requiring more insight into mission life time. The system reliability model encompasses radiation effects, natural aging, operating temperature effects and usage duty cycles that are common to all other JPL flight projects. It captures the systems engineering practices and processes that allow any mission to perform credible characterization of lifetime, thus enabling trades at the system level. The system reliability model and processes leading to it provide a systematic approach to understand the mission lifetime predictions for Titan and other future long duration missions.

2.2 Environment and Shielding Models

2.2.1 Introduction

An integral part of the radiation risk mitigation design process is to understand the external and internal radiation environments. Correctly defining the radiation environments is essential for every aspects of mission and spacecraft design. These include optimizing the trajectory to minimize radiation exposure, determining mission lifetime, selecting parts, materials, detectors and sensors, and designing shields. For the proposed JEO mission, the dominant contributor to the overall mission radiation environment is the high-energy trapped particles at Jupiter. The Jovian trapped particles are not static, but vary in intensity and population spatially and temporally. Understanding these variations and their associated uncertainties are important not only for the accurate environment estimate for the mission, but also as a critical input to the statistical mission lifetime study.

Our present understanding of the uncertainties associated with the Jovian radiation environments external and internal to spacecraft is limited. Further refinement of the radiation environment model is critical because:

- Measured data are scant, but even those limited data are not fully considered in the current model.
- Temporal variation of the environment is not well characterized.
- Directionality of the environments around the Europa orbit needs to be refined.
- The accuracy of nuclear/atomic interaction cross sections used in transport codes is not well understood.
- The process of system level shielding analysis is not efficient.

All these factors may contribute to conservative mission and spacecraft design with excessive margins.

2.2.2 Objective and Approach

The objective of this WBS element is to better characterize and reduce the uncertainties in the external Jupiter/Europa environment and the shielded environment within the spacecraft. ESA has also developed a radiation environment model which produces different results when compared with the JPL model. The implementation approach is to initiate a national and international effort for developing a radiation environment model specifically tailored for EJSM. The tasks planned for the four years are:

(1) to work with international partners to ensure that the environment models used at NASA and ESA are consistent;
(2) to perform data analysis and a theoretical study to better understand the spatial and temporal distributions of Jupiter-Europa environments;
(3) to update our current Galileo Interim Radiation Electron (GIRE) model by incorporating all available data (e.g., Galileo (GLL) protons, GLL heavy ions, Pioneer high-energy electrons), augmented by a theoretical model (e.g., Salammbo);
(4) to examine adequacy of nuclear/atomic interaction cross section data used in representative transport codes; and

(5) to demonstrate the efficiency of using a Computer-Aided Design (CAD) tool interface program for mass modeling of shielding analysis.

2.2.3 Roadmap and Schedule

Figure 2.2 shows the roadmap and schedule of this WBS element. The tasks are prioritized based on the mission-level milestones.

Specific deliverables for each year are:

- FY'08: Radiation environment estimate for the 2008 JEO mission.
- FY'09: Comprehensive high energy electron data set from Pioneer, Voyager, and Galileo. Electron model update in GIRE; Consistent environment models at NASA and ESA.
- FY'10: Proton model update in GIRE. Shielding uncertainty input to system model.
- FY'11: Heavy ion model update in GIRE; Local environment model update in GIRE; Temporal spatial uncertainty input to system model.

2.2.4 Applicability to Other Missions

This WBS element is unique to EJSM and Jovian environment, in general, not applicable to possible future Titan and other non-Jovian environment missions.

ENVORONMENT AND SHIELDING MODEL		**Capabilities implemented by Version**			
		Version 1	**Version 2**	**Version 3**	**Version 4**
	JPL SOA	**FY08**	**FY09**	**FY10**	**FY11**
ENVIRONMENT MODEL OVERVIEW					
Key Features					
External environment model uncertainty: spatial	Basic/ Quantitative		Medium	Medium-Low	Low
External environment model uncertainty: temporal	Limited/Qualitative			High	Medium
Uncertainty in shielded environment within the spacecraft	Limited/Qualitative		High-Medium	Medium	
ENVIRONEMT MODEL					
Proton model	*Pioneer Data*				Final
Heavy ion model	*Pioneer Data*			Final	
Local environment at Europa: directionality	*None*			Preliminary	Final
Temporal behavior of the radiation environment at Europa	*None*			Preliminary	Final
Radiation environment estimate for new trajectory	*N/A*	Ongoing	Ongoing	Ongoing	Ongoing
Consistent environment estimate between NASA and ESA	*N/A*		Final		
High energy electron data set	*Separate and inconsistent data set from several spacecraft*		Final		
SHIELDING MODEL					
Uncertainty with shielding model					
Interaction cross sections	*None*		Initial	Final	
Mass modeling	*None*		Initial	Final	
GUIDELINES(*)					
Tutorial materials for envionment and shielding	*EE2007 Study*	Final			
Shielding design guideline	*None*		Draft		Final
IESD mitigation guideline	*NASA HDBK 4002A*	Draft	Final		

Figure 2.2 WBS 2.0 Roadmap – Environment and Shielding Models

2.3 Radiation Design Methods

2.3.1 Introduction

The traditional methods for designing and verifying spacecraft electronics subsystems often lead to an overly conservative system design. This commonly results from a compounding effect of applying worst-case assumptions at every level. For example, a parts data base is normally constructed that includes degradations (due to radiation, power supply variation, end-of-life, and part-to-part variation) for each component parameter, and often an additional safety margin is levied on the part parameters.

A worst case analysis (WCA) using extreme value analysis (EVA) is then conducted using these part parameters, with the requirement that the circuit still function when subjected to the worst possible combination of part parameters each at its extreme value. Typically, parts on the same board are assumed to be at different temperature extremes if it drives the worst-case scenario, even if it is virtually impossible that this could occur.

In the event that the initial circuit fails to meet the WCA, for example, due to radiation effects, one approach is to provide spot shielding for the component. However, in designing the spot shield, the packaging engineer is often required to provide twice as much shielding as is deemed to be necessary to allow for higher uncertainties in the shielding analysis. As such, due to a compounding effect of conservatism at several levels, a traditional flight system and electronics subsystem design would contain excessive margins that limit resources available for mission science.

The proposed JEO mission would require improved design techniques and methods to demonstrate the ability of flight engineering subsystems to operate in the Europa radiation environment for an acceptable mission lifetime. Traditional analysis tools such as WCA may provide overly conservative analysis for the proposed JEO mission.

2.3.2 Objective and Approach

The objective of this WBS element is to create a set of techniques and guidelines for use by instrument and spacecraft developers that would result in designs with more predictable failure characteristics. The implementation approach is to investigate the approach to WCA to better understand the relationships between the input parameters and the predicted circuit performance. Several notional circuits known to be susceptible to the radiation environment would be designed, bread-boarded, analyzed and radiation tested to create a basis for showing that the techniques could be adequately executed and described for circuit designers. The benefits of promoting the use of common techniques across the flight system are to reduce the cost and schedule risk associated with similar types of errors made in different designs.

2.3.3 Roadmap and Schedule

Deliverables of this effort must be generated in a timely fashion in order to provide enough lead time to take advantage of the improvements provided by these techniques and guidelines. The 1st version of these guidelines is needed for the November 2009 Instrument workshop. To support this effort, tutorials and guidelines for the Europa environment and shielding, as well as tutorials and guidelines on materials, must be completed by July 2009. Figure 2.3 shows the roadmap of this WBS element.

The key products of this WBS element are:

- A set of design guidelines for use by instrument and spacecraft developers
- Information for flight system developers on the mission radiation environment and shielding techniques
- Design and analysis guidelines for parts de-rating, WCA, and circuit performance
- Parts testing requirements for parts degradation and actual failure characteristics
- A set of general purpose circuit designs that have been demonstrated for application across the flight system

Specific deliverables for each fiscal year are shown in Figure 2.3.

RADIATION RISK MITIGATION ROADMAP	JPL SOA	FY07	FY08	FY09	FY10	FY11
PROJECT MILESTONES					MCR ▽ IAO ▽	▽PMSR
3.0 Radiation Design Methods	None					
Shielding Tutorial & Guidelines		Draft	Draft	Final		
Charging Mitigation Guidelines		Draft	Draft	Final		
Radiation Design Tutorial & Guidelines		Draft	Draft	Final		
FPGA to ASIC Conversion Design Guidelines		Draft	Draft	Preliminary	Revision	Final
Materials Tutorial & Guidelines		Draft	Draft	Final		
Subsystem & System (WCA) Design Guidelines		None	Initial Design	Fab HW & Rad Test	Design Iteration & Final Rad Test	Final
Long Life Design Guidelines		None	Draft	Preliminary	Revision	Final
Radiation Engineering Plan		None	Draft	Preliminary	Revision	Final
Bus Core FPGA ASIC Architecture (MSAP)				Preliminary	Revision	

Figure 2.3 WBS 3.0 Roadmap – Radiation Design Methods

2.3.4 Applicability to Other Missions

This WBS element is, in general, applicable to all missions in terms of the process methodology that is being developed. These include: 1) Guidelines for converting FPGAs to ASICs, and/or using FPGAs as intermediate products for ASICs; 2) Improvements in WCA to remove excess design margins from the traditional approach; and 3) Guidelines for long life design, which cover numerous topics beyond radiation.

2.4 Sensors and Detectors

2.4.1 Introduction

Radiation-induced effects on instrument detectors and other key instrument components are significant issues that ultimately impact the quality and quantity of the mission science return and the reliability of engineering sensor data critical to flight operations. High-energy particles found within the harsh Europa environment will produce increased transient detector noise as well as long-term degradation of detector performance and even potential failure of the device. Transient radiation effects are produced when an ionizing particle traverses the active detector volume and creates charges that are clocked out during readout. Radiation-induced noise can potentially swamp the science signal, especially in the infrared wavebands where low solar flux and low surface reflectivity result in a relative low signal. Both total ionizing dose (TID) and displacement damage dose (DDD) effects produce long-term permanent degradation in detector performance characteristics, such as a decrease in the ability of the detector to generate signal charge as well as to transfer that charge from the photo active region to the readout circuitry, shifts in gate threshold voltages, increases in dark current and dark current non-uniformities, and the production of high-dark-current pixels (hot pixels or spikes). It is important to identify and understand both the transient and permanent performance degradation effects in order to plan early for appropriate hardware and operations risk mitigation to insure mission success and high-quality science returns.

Our understanding of these effects for the Europa environment is hampered due to scarce data exists for electron-induced DDD effects, which is the dominant radiation dose imparted at the end of the proposed JEO mission. The majority of the literature on displacement damage effects in detectors is concerned with proton-induced DDD, as this is dominant dose in Earth orbit, and the relationship between electron-induced and proton-induced DDD is not well understood today. Also adding to the challenge, room-temperature radiation tests could significantly under estimate performance problems encountered under flight conditions.

Also included this activity is consideration of the impact of PP requirements on payload science and engineering sensors. The use of DHMR (elevated temperature), which is the current baseline approach for the proposed JEO, presents a challenge to many photon detectors because of potential degradation of the active material and/or of the device packaging. These requirements may significantly impact the selection of detector technology, implementation of that technology, and overall implementation of the instrument subsystems.

2.4.2 Objectives and Approach

The objective of this WBS element is to show a feasible pathway for science and engineering detectors and other key components that are unique to the payload. The implementation approach for accomplishing this objective involves:

(i) Assessing the radiation susceptibility of the potential detector and component technologies required by the notional planning payload recommended by the EJSM Joint Science Definition Team (JSDT);
(ii) Filling critical knowledge gaps in our understanding; and
(iii) Identifying possible mitigation approaches.

Based on the planning payload, the following technologies will be evaluated:

- Visible imagers
- Infrared detectors (1 – 5 μm and 8 – 26 μm wavebands)
- Avalanche photodiodes
- Microchannel plates, photomultipliers, and enhanced charge-coupled devices
- Other key components such as lasers and optical elements
- Star tracker detectors

Initial assessment of these technologies involves a review of the available literature and accessible TID/DDD test data for each technology to determine known radiation susceptibility. When existing test data are not adequately representative of the proposed JEO mission conditions, additional testing would be recommended to fill the knowledge gap. Specific deliverables of each task include:

- FY'08: Review of the existing literature and available test reports on the technologies listed above; and assessment of existing star tracker detectors, incorporating Juno test data and lessons learned;
- FY'09: Modeling of the secondary radiation environment at the component behind various shielding configurations; and Modeling and model validation of the radiation-induced transient noise for selected notional detectors;
- FY'10: TID testing of a range of CMOS imaging test structures to demonstrate the feasibility of a hardened-by-design CMOS imager;
- FY'11: Recommendations, if any, for additional TID and/or DDD testing of selected notional detectors.

Ultimately, the payload providers that are selected for the proposed JEO would be responsible for the detector-specific testing for their particular instrument. A particular instrument provider's solution would likely involve operational conditions and readout approaches (or even focal plane array (FPA) technology choices) that may be hard to second guess in a more abstract "general" test campaign before instrument down select. Since the instrument performance impact of so many FPA radiation degradation mechanisms is driven by the particular operational conditions and modes being used, this needs to be considered with respect to test validity. This type of testing (under flight representative conditions) should not be underestimated with respect to difficulty and cost, so validity becomes proportionately more important and instrument providers should start their test programs as early as possible.

2.4.3 Roadmap and Schedule

Figure 2.4a shows the roadmap and the time phasing of the tasks for this WBS element over the next four years. A schedule with major milestones is also provided in Figure 2.4b.

4.0 DETECTORS & SENSORS	JPL SOA	FY08	FY09	FY10	FY11
PROJECT MILESTONES					
DETECTORS & SENSOR OVERVIEW					
Key Features					
System-level understanding of detector radiation risk		Low	Medium	Medium	High
Knowledge of performance characteristics of detectors under EO environment		Low	Medium	Medium	Medium
4.1 Management & System Engineering					
4.1.1 Assessment of radiation effects on instruments & detectors	N/A				
Identify notional science & engineering detectors & other instrument rad-sensitive components		Final			
Determine radiation environment at detector/component w/ shielding		Final			
Establish detector/component performance requirements for notional instruments		Final			
Review existing TID/DDD radiation test data on relevant detectors and key instrument components		Final			
Develop component -specific radiation test plans when existing data is not representative of EO flight conditions		Preliminary	Final		
4.1.2 Deliver report: Assessment of Radiation Risk for Science Instruments	N/A	Final			
4.2 Science Sensors: Modeling & Testing					
4.2.1 Model & validate electron-induced transient noise in selected detectors	N/A	Modeling	Model validation		
4.2.2 Conduct TID testing of JPL CMOS visible imager test structures	N/A	Preliminary	Final		
4.2.3 Conduct additional TID/DDD testing of selected science detectors & key instrument components	N/A		Interim	Interim	Final
Visible imagers					
Infrared sensors (1–5 µm, 8–25 µm)					
Avalanche photodiodes					
Microchannel plates, photomultipliers, enhanced CCDs					
Other key components (lasers, optical elements, etc)					
4.3 Engineering Sensors: Assessment & Testing					
4.3.1 Evaluate star tracker detectors	N/A	Final			
4.3.2 Conduct additional TID/DDD testing of star tracker detector	N/A	Preliminary	Final		

Figure 2.4a WBS 4.0 Roadmap – Sensors & Detectors

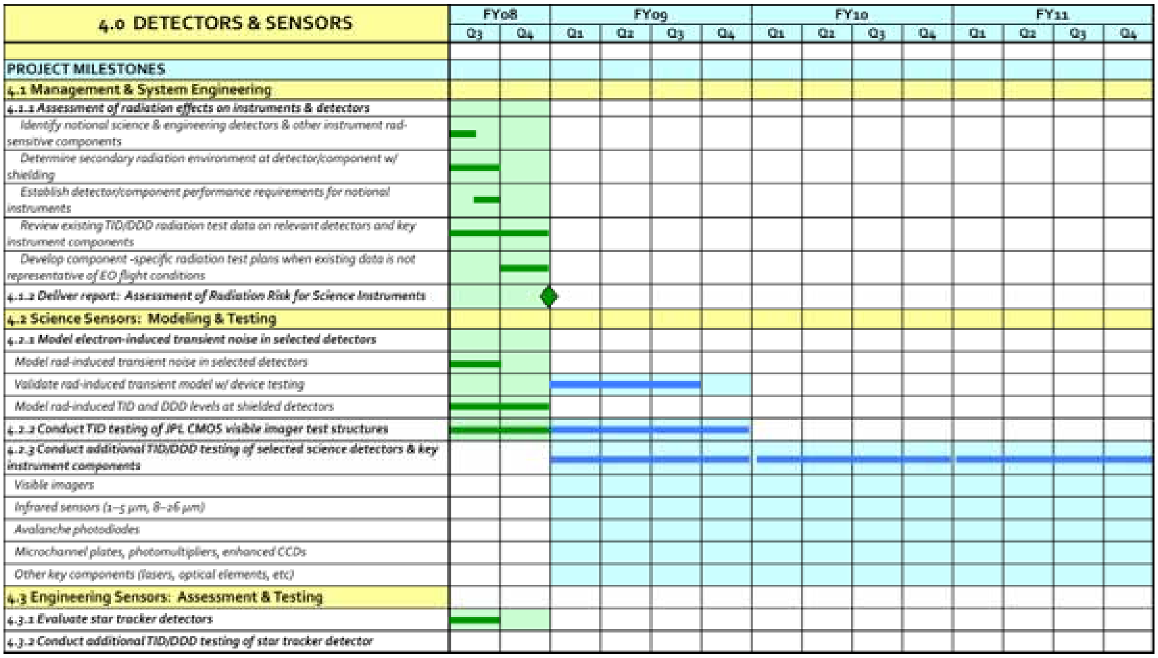

Figure 2.4b WBS 4.0 Schedule – Sensors & Detectors

2.4.4 Applicability to Other Missions

This WBS element is unique to EJSM and, in general, not applicable to possible future Titan and other non-Jovian environment missions.

2.5 Parts Evaluation and Testing

2.5.1 Introduction

The majority of NASA's radiation test and life test data on electronic parts was taken in support of missions with low radiation requirements (<50 Krad) and short life times (<5 years). Commercially available parts advertized to be compatible with environments of 100 krad up to over 1 Mrad are generally not heavily used nor tested for long duration missions. Parameter degradations due to high radiation exposure levels have not been fully characterized and documented. As such there is limited data to support parts selection and WCA, and determination of risk areas for aggressive radiation environment experienced by the proposed JEO mission. An early start on the test and evaluation of different device families would alleviate many problem areas and, therefore, aid in the early assessment and retirement of risks.

Overly conservative radiation test and analysis methods would quickly exhaust the resources available for missions with aggressive radiation environments. Typical missions employ worst case conditions for testing to ensure that mission conditions are bounded and these conditions do not impose stressful design constraints. For the proposed JEO mission, the existing test and evaluation methods could result in excessive conservatism in the development of worst case design parameters and significant unnecessary costs for radiation testing. For example, a typical low dose rate testing intended to address Enhanced Low Dose Rate Sensitivity (ELDRS) is carried out at dose rates between 5 and 10 mR/s. At these dose rates, tests for missions with dose levels in the hundreds of Krads would take longer than one year. The end result is significant cost to the mission for all parts requiring similar tests. Development of accelerated test methods would result in significant cost savings. However, these test methods would need to be validated over a range of device processes.

Further, typical test methods for total dose in CMOS devices do not account or allow for annealing effects. On long duration missions, some parts could survive higher TID if annealing is considered. This has been observed based on Galileo data collected during the Jupiter encounter. Presently no guideline or method exists to address the benefit of annealing to extending device performance. This work element evaluates areas where annealing effects might be a benefit and develops a guideline for including annealing in test and acceptance of devices.

The following device technologies were identified as critical areas where significant risks would be mitigated by efforts to focus on the evaluation, testing and characterization of the devices early in the planning and development cycle. Timely assessment of radiation susceptibility and reliability would result in a reduction of risk and cost for spacecraft and instrument providers of the proposed JEO mission. The device technologies are:

- Non-Volatile Memory radiation susceptibility and reliability
- FPGA availability and reliability
- Power converter radiation susceptibility and reliability
- Micro Processor/Microcontroller radiation susceptibility and reliability
- Data Bus Device availability
- Linear Device radiation susceptibility

2.5.2 Objective and Approach

The objectives of this WBS element are to improve and extend existing radiation and life test database to support device selection and approval for high radiation and long life missions, provide supporting data for device selection and addition to the APML, and to develop evaluation and test techniques. The approach includes radiation and reliability tests to validate device performance, radiation characterization to evaluate test methodology, and evaluation of existing radiation hardened devices acceptable for the Europa environment. The implementation approach is to evaluate radiation test methodologies, extend ongoing radiation tests to the proposed JEO level, and evaluate and test of key device technologies.

Radiation test methodology – Evaluation of the benefits of annealing in mission scenarios would be performed by evaluating annealing results from extended testing, evaluating the results by device type and developing a guideline for radiation lot acceptance including annealing methods for long duration missions. Low dose rate test methods would be developed using the results of extended low dose rate testing and evaluating against the mission dose rate profile. Further, the mechanisms for displacement damage effects in high energy electron environments would be evaluated to determine an effective test method for displacement damage effects. The end product would define device testing methods for evaluation and qualification of devices for the proposed JEO mission.

Extension of existing radiation tests – The Juno mission is in the process of performing characterization and radiation lot acceptance data to 50 to 100 Krad. By extending these tests to higher dose levels data could be used in support of the proposed JEO mission. The extended dose level data can be obtained with a significant savings in non-recurring engineering costs. The data thus obtained can be used to verify accelerated test methods, identify or eliminate candidate devices and provide statistical data for evaluation of worst case design parameter methods.

Key device technology evaluation and tests – Tests would be performed on selected critical device technologies as follows:

- For non-volatile device technologies, radiation and reliability tests would be performed to obtain an initial evaluation of target technologies as well as alternate device types.
- For FPGAs the task is to evaluate available devices for radiation and long term reliability. The objective is to determine what, if any, available device technologies would meet the long term reliability needs of the proposed JEO mission. Approach is to evaluate existing data on available devices, perform any needed endurance or reliability testing, report results, and provide recommendations.
- Evaluation of existing power converter designs, both commercial and JPL based designs would be performed to assess power distribution methods; and recommend the most cost effective paths for the mission.
- The availability and capability of micro-processors/controllers and data bus devices would be assessed to determine devices which are acceptable for use in high radiation long duration missions.
- Evaluation of linear devices (and other critical devices) would be performed to identify acceptable devices for the mission.

Specific deliverables for each fiscal year are shown in Figure 2.5a.

RADIATION RISK MITIGATION ROADMAP	JPL SOA	FY07	FY08	FY09	FY10	FY11
PROJECT MILESTONES					MCR ▽ ▽ I AO	▽PMSR
5.0 Parts Evaluation & Testing	N/A					
Annealing Effects Evaluation & Guidelines			Preliminary	Final		
Testing Strategy & Guidelines (ELDRS, Displacement, Combined TID/Displacement)			Evaluation & Recommendation	Preliminary Req Doc	Final Req Doc	
Juno Extended Testing			6	18	22	24
Device Evaluation & Testing (Non-Volatile Memories, FPGA, Power Converters, Micro-processors/Controllers, Data Bus Devices, Linear)		Limited	Preliminary	Final	Final (Linear)	Final (Linear)

Figure 2.5a WBS 5.0 Deliverables – Parts Evaluation and Testing

2.5.3 Roadmap and Schedule

Figure 2.5b shows the roadmap for the above activities and the time phasing of the tasks for this WBS element over the next four years.

2.5.4 Applicability to Other Missions

This WBS element is, in general, applicable to all missions. The testing strategies and guidelines for ELDRS and displacement damage are fundamental to other missions requiring attention to radiation environments; even low radiation missions such as Mars and Earth orbiters. The New Frontier's Juno Jupiter mission would be a beneficiary if these procedures were available prior to the completion of flight lot radiation testing. The availability of radiation-hardened micro-processors and controllers, memory devices and other linear devices allows significantly less shielding mass requirements for mission design trade-offs. Device evaluation and reliability testing would provide supporting data for the evaluation of devices for long duration (> 5 years) missions.

Parts Evaluation and Testing	JPL SOA	FY07	FY08	FY09	FY10	FY11
					MCR ∇ IAO∇	∇MSR
Data Reduction S/W	N/A					
Data report requirements			Final			
LTS2020 S/W			Final			
Eagle ETS300			Preliminary	Final		
Advantest 2000			Preliminary	Final		
Annealing Effects Evaluation	N/A					
Initial evaluation and recommendations report			Final			
Plan/Identify device types			Preliminary	Final		
Perform Device testing/complete reports			Preliminary		Final	
Guideline/Requirements for inc. of Annealing				Preliminary	Final	
Testing Strategy	N/A					
Complete initial ELDRS test evaluation and document recommendations			Preliminary		Final	
Complete initial Displacement test method evaluation and document recommendations				Preliminary	Final	
TID/DD combined effects testing				4		
Document Requirements for ELDRS and TID/DD testing				Preliminary	Final	
Testing Strategy	N/A					
Juno extended testing completion			6	18	22	24
NVMemory Test and Evaluation	N/A					
BAE CRAM						
Test Plan and procure devices			Final			
Perform Rel and Rad testing			Preliminary	Final		
Report			Preliminary	Final		
Samsung CRAM						
Test Plan and procure devices			Final			
Perform Rad testing			Preliminary	Final		
Report			Preliminary	Final		
MRAM						
Test Plan and procure devices			Final			
Perform Rel and Rad testing (COTS and Honeywell)			Preliminary	Final		
Report			Preliminary	Final		
SDRAM						
Test Plan and procure devices			Final			
Perform Rel and Rad testing			Preliminary	Final		
Report			Preliminary	Final		
FPGA Evaluation	N/A					
Evaluate available data on FPGAs			Preliminary		Final	
Report findings/recommendations			Preliminary			Final
Power Converter Test/Evaluation	N/A					
Obtain devices complete Plan			Preliminary		Final	
Complete report and Recommendations			Preliminary		Final	
uProcessor/Controller Assessment	N/A					
Perform asesssment			Final			
Report Recommendations				Final		
LEON 3 Aeroflex test				Preliminary	Final	
Data Bus Devices	N/A					
Perform asesssment				Final		
Report Recommendations				Preliminary	Final	
Linear Devices	N/A					
Perform asesssment and tests					Final	
Report Recommendations					Preliminary	Final

Figure 2.5b WBS 5.0 Roadmap – Parts Evaluation and Testing

2.6 *Approved Parts & Materials List (APML)*

2.6.1 Introduction

The Europa radiation environment is very harsh and many standard parts will not meet the specific radiation tolerance requirements. Though many parts are functional after exposure to this environment, the parameter degradation may be different from typical parameters shown on specification sheets from vendors. The focus of this WBS element is to have an early assessment of parts available for the proposed JEO mission and to pre-screen acceptable parts, quantify the design parameters and list and specify any additional evaluation required for parts and materials. Dissemination of this information early in the design process is critical to enable engineering and payload providers to adequately design for the aggressive radiation environment. In addition, the development of the Part Program Requirements is crucial to communicate with potential providers the requirements for Electronic, Electrical, and Electromechanical (EEE) parts for the mission including how and when to use the APML. This allows effective development procedures for spacecraft and instrument providers.

2.6.2 Objective and Approach

The objective of this WBS element is to develop a web-based APML which consists of pre-selected parts and materials that meet the mission radiation requirements. This would improve efficiency in part/material selection and reduce development cost and risk. The implementation approach is to populate the APML with acceptable Juno parts and vendor radiation hardened parts that meet various radiation environments including those for a possible future Titan mission. Also included would be a risk assessment of general materials classes and what additional testing would be required. The APML would be populated with Worst Case Data (WCD) and application notes for specialty parts (e.g. sensors, detectors, DC/DC converters, FPGAs, and non-volatile memory). Designers would be able to select parts and materials from the APML. In the case that a part cannot be located in APML and an alternate design cannot be formulated, a process would be in-place to evaluate unique parts or materials. This process would be described in this APML. The APML would be updated quarterly as new radiation data become available, including Juno extended test results.

Specific milestones for each fiscal year:

- FY'08: Generate Parts Program Requirements for possible future Europa and Titan missions; identify APML format and populate with available radiation hard parts, materials, and processes (150 parts & materials listed. 20 WCD); identify the best suited web-base data base for APML; and validate radiation models for 5/11 part families.
- FY'09: Finalize choice of data base, and update the list with newly tested parts including the Juno extended parts (300 + parts, 50 WCD); validate radiation models for 8/11 part families
- FY'10: Update APML as new data becomes available; validate radiation models for 11/11 part families
- FY'11: Update APML quarterly as new data becomes available

2.6.3 Roadmap and Schedule

Figure 2.6a shows the roadmap for the above activities and the time phasing of the tasks for this WBS element over the next four years. A schedule with major milestones is also provided in Figure 2.6b.

RADIATION RISK MITIGATION ROADMAP	JPL SOA	FY07	FY08	FY09	FY10	FY11
PROJECT MILESTONES					MCR ▽ IAO ▽	▽PMSR
6.0 Approved Parts & Material List	**None**					
Project Parts Requirements Document			Final			
Preferred Parts & Material List (PPML) and Worst Case Data sheet (WCD)			150 parts & material list and 20 WCD	300+ parts & material list, 100+ WCD	Quarterly Updates	Quarterly Updates
Parts Parametric Design Approach			5/11 part families	8/11 part families	11/11 part families	

Figure 2.6a WBS 6.0 Roadmap – Approved Parts and Material List

		2008									FY2009												FY2010	FY2011
Task Description	Assignee	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
Generate initial list from existing JUNO parts list	Nayla																							
Initial review, clean-up the list	Nayla/Steve																							
Change format to APML agreed format	Nayla																							
APML list review by parts specialist	Specialist group																							
APML list review by radiation specialist	Rad group																							
Send a copy of the list to 513 for WCD	513																							
Review list for GIDEP alert	Nayla																							
Organize Parts Control Board	Nayla																							
First release excel format APML																								
Workshop #2 part selection from APML tutorial																								
Keep updating APML by adding new parts	PCB Team to approve																							
Evaluate and select data base format	PCB Team																							
Data base Development																								
Keep updating APML by adding new parts	PCB Team																							
Instrument AO, 300+ parts and 50WCD web based APML	PCB Team																							
Update and release APML quarterly	PCB Team																							

Figure 2.6b WBS 6.0 Schedule – Approved Parts and Material List

2.6.4 Applicability to Other Missions

This WBS element develops an integrated process to approve parts and materials for missions in general. It further provides worst-case parameter design guidelines for each approved part. The availability of radiation-hardened parts and materials organized in a web-based searchable manner significantly reduces the effort required for selection and evaluation of parts and materials for any mission designer. Use of standardized parts would further reduce costs for qualification and procurement and encourage standard design practices. The New Frontier's Juno Jupiter mission would be a beneficiary if the list were available prior to completion of the mission design. The basic structure of APML and approaches developed in this activity are applicable to other missions.

3. Reviews

The original version of this plan was presented at a half-day workshop at JPL with JPL and APL participation on February 11, 2008. It was further developed, refined and reviewed by the Office of Mission Success at JPL on March 7 2008.

Monthly Management Review (MMR) would be conducted to manage this activity.

Quarterly technical reviews would be conducted with the APL and JPL engineering experts.

Annual peer reviews would be conducted to gain the insight of the technical discipline experts.